The impact of EU ETS verification events on stock prices

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Abstract: In this study we investigate how the publication of verified emissions in the European Emissions Trading Scheme (EU ETS) affected stock prices of covered companies. Based on a unique sample of 368 listed companies located in 25 countries, the event study demonstrates that 2 out of 6 publication events over the period 2006-2011 resulted in statistically significant market responses. The two significant events were the first publication of verified emissions in the first phase, a pilot period that ran from 2005 to 2007, and the first publication in the second phase, coinciding with the Kyoto Protocol commitment period and comprising the years 2008 to 2012. These findings indicate that investors value particularly the information revealed at the first verification event of each EU ETS phase and that subsequent verification events are less informative. The cross-section analysis of abnormal returns surrounding the publication of verified emission does not yield consistent results. While the analysis of the first publication in the first phase provides insignificant results, we find a significant negative correlation between the market reaction and the level of unexpected verified emissions during the first publication in the second phase. This negative relationship is found to be significantly stronger for carbon-intensive firms. These different results suggest that investors' perception towards emission allowances has changed between the first and second phase.

Keywords: Event study, absolute abnormal returns, EU ETS, verified emissions, carbon trading

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1. Introduction

The development and increase in the number of carbon emissions schemes around the world, as a response to the growing concern about climate change, has resulted in the emergence of carbon permits as a conventional commodity. Emission trading is an important mechanism of the Kyoto Protocol and has enabled the financial markets to put a price on carbon emissions, thereby creating an incentive for companies to reduce their emissions (European Commission, 2009). The practice of emissions trading is not particularly novel. Trading of sulphur dioxide (SO_2) and nitrogen oxides ($NO_{x)}$ began in the United States in the 1990s (Hepburn, 2007). Carbon trading, which refers to the trading of emission allowances of six major greenhouse gases[2] is more recent. The European Union (EU) launched an EU-wide emissions trading scheme (EU ETS) for CO_2 emissions in 2005 which can be considered as the cornerstone of the EU climate policy. The EU ETS was the first and is to date the biggest international system for trading greenhouse gas emission allowances, covering almost half of EU's greenhouse emissions and operating in 31 countries (European Commission, 2013).[3] The EU ETS has been designed to operate in different phases. Phase 1 ran between 2005 and 2007 and could be regarded as a start-up and test period. Phase 2, which comprised the years 2008 to 2012, coincided with the Kyoto Protocol commitment period and required EU Member States to achieve an 8% emission reduction compared with their 1990 level. Phase 3 has the longest compliance period, from 2013 to 2020. Its target is to reach by 2020 an emissions level of 21% less than the 2005 level (Mnif and Davison, 2012).

The idea of the EU ETS is that carbon-intensive companies have to surrender allowances equivalent to the number of carbon emissions caused by their installations. Companies with excess allowances can sell their surplus allowances on the market and analogously, companies can buy allowances if their abatement price is above the EU permit price (Hoffmann, 2007). In other words, putting a price on the right to emit carbon dioxide has turned a firm's carbon performance[4] into a potential financial component of investment analysis. Johnson et al. (2008) provide evidence for the value relevance of a firm's carbon performance. The authors analyze the market value of excess allowances within the context of the $U.S.$ SO_2 trading scheme and conclude that the capital market assigns a positive price to a firm's excess allowances.

Carbon performance could also be important to investors in a non-financial way. There is a growing appetite for climate change related information within the investment community. Investors and other stakeholders are increasingly seeking relevant information about a company's footprint and the effects of climate change on company performance and prospects (Graham, 2009). Eccles et al. (2011) provide insights into market interest in nonfinancial (e.g. environmental, social and governance) information. The authors show that there is a large market interest in company's degree of transparency around environmental performance and

[2] These are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorcarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6).

[3] The EU ETS operates in the 27 EU countries, the three EEA-EFTA states (Iceland, Liechtenstein and Norway) and Croatia (joined in 2013).

[4] According to Hoffmann and Busch (2008) carbon performance can be measured by 4 carbon indicators: Carbon intensity, carbon dependency, carbon exposure and carbon risk.

policies and that, from the set of environmental metrics, the highest market interest is shown for greenhouse gas emissions.

In this study, we examine whether the carbon performance of companies contains value-relevant information. In a first step, we try to investigate, by using the event study approach, if the 6 annual EU ETS verification announcements over the period 2006-2011 conveyed valuable information to investors for publicly traded companies in 25 European countries. In a second step we regress the announcement effect on EU ETS emissions data.

The results of the event study demonstrate that the first publication in Phase 1 and the first publication in Phase 2 resulted in statistically significant market responses. These findings indicate that investors valued particularly the information revealed at the first publication of verified emission in the first EU ETS phase (2005-2007) and the first verification event in the second phase (2008-2012). Subsequent verification events in each phase seem to have been less informative as the first verification event probably served as a benchmark on the basis of which future carbon performance is forecasted. The cross-section analysis of abnormal returns surrounding the publication of verified emission does not yield consistent results. While the analysis of the first publication in the first phase provides insignificant results, we find a significant negative correlation between the market reaction and the level of unexpected verified emissions during the first publication in the second phase. This negative relationship is found to be significantly stronger for carbon-intensive firms. These different results suggest that investors' perception towards emission allowances has changed between the first and second phase.

The value of carbon performance, within the context of the EU ETS, has only scarcely been studied. Bushnell et al. (2011) conduct an event study to analyse the impact of the carbon price crash in late April 2006 on firms covered by the EU ETS. The authors provide evidence for a sector specific reaction to permit price changes and report that the firms with the largest allocated allowances experienced the largest abnormal declines. This result indicates that the market regards emission allowances as a valuable asset. Schmidt and Werner (2012) examine the relation between stock returns and the announcements of verified emissions. They use a small sample of listed firms from Austria, Denmark, Germany and the UK. The most noteworthy results from this study are the negative effects from over-allocation on the announcement effect in 2006 and the reverse relationship in 2009. Abrell et al. (2011) investigate the impact of the EU ETS, using panel data on the emissions and performance of participating firms. The authors conclude that the emission scheme had only a modest impact on the covered companies' profitability.

Our study contributes to this limited literature by examining how the publication of verified emissions in the European Emissions Trading Scheme (EU ETS) affected stock prices of a unique sample of 368 covered companies, representing 25 countries. In contrast to other studies using carbon emissions firm-level data (e.g. Schmidt and Werner, 2012) we cover the entire European Union. Second we investigate 6 publication events over the period 2006-2011 comprising both EU ETS phases. Third, we analyze the determinants of abnormal returns using both actual and expected verified emissions.

The remainder of the paper is organized as follows. In section 2 we present an overview of the related literature. In Section 3 we state our hypotheses. Section 4 presents the data and section

5 describes the methodological procedure and analyses the empirical results. Section 6 concludes.

2. Literature

In this section we briefly describe some studies examining the link between environmental performance and firm performance, followed by a description of the allocation and verification process of the EU ETS. We end this literature review by discussing studies that investigate the effect of the EU ETS on firm performance.

2.1 Environmental performance and firm performance

The relationship between environmental performance and financial performance has been studied by numerous researchers. Some authors analyse the link between environmental performance and long-term financial performance indicators such as Tobin's Q (Clarkson, 2004; Guenster et al., 2011; Nishitani and Kokubu, 2011). Others focus on the impact of environmental disclosure on short-term shareholder wealth effects by conducting event studies (Jacobs et al, 2010; Curran and Moran, 2007; Dasgupta et al., 2004).
To stay close to the subject of this study, we will only discuss studies concerning the impact of reports about greenhouse emission levels. Konar and Cohen (2001) explore the relationship between firm-level environmental performance and intangible asset value of S&P 500 firms. The authors find that poor environmental performance, measured as toxic chemical emissions, has a significant negative effect on intangible asset values. This negative relationship between company value and carbon emissions has been confirmed by Griffin et al. (2012) and Lee et al. (2013), both using the event study methodology. Lee et al. (2013) investigate market responses to firms' voluntary carbon disclosure by using a sample of Korean firms and suggest that the market responds negatively to firms' carbon disclosure. Griffin et al. (2012), using companies that disclose greenhouse gas emissions voluntarily through the Carbon Disclosure Project, show that investors use emission information to assess company value. Their stock price analysis suggests that emission levels are negatively associated with stock prices. Much of the research on the relationship between emission data and firm performance has focused on voluntary disclosure. Our study however, is closer related to studies that examine the influence of compulsory emission trading schemes. Examples of such studies are the U.S. Toxic Release Inventory reports (e.g. Hamilton, 1995; Khanna et al., 1998), the U.S. SO_2 emission trading scheme studies (e.g. Hughes, 2000) and the Australian ETS reports (e.g. Chapple et al., 2011). Hamilton (1995) assesses the market reaction to the first announcement of Toxic Release Inventory data. The results of this study reveal that firms experienced an average loss of $4.1 million in market value on the day when the TRI data were released. Further, Hamilton (1995) finds that firms with higher emissions received more media coverage. Khanna et al. (1998) study the influence of 6 consecutive publications of TRI data over the period 1989-1994. They find significant negative abnormal returns on the day following the release of TRI data for the years 1991-1994. Hughes (2000) analyzes the market reaction to the announcement of SO_2 emission data for a sample of high-polluting utility firms and his results reveal that SO_2 emissions are negatively related to market value. Turning to the

Australian context, Chapple et al. (2011) identify five distinct information events argued to impact the probability of a proposed emission trading scheme being enacted and find evidence that the capital market prices the proposed ETS. The authors find a negative reaction to all four events argued to increase the likelihood, although only one was statistically significant, and a significant positive reaction to the one event argued to decrease the likelihood of an emission trading scheme. Further, when the authors divide their sample into high and low carbon-intensive firms, they detect a stronger market reaction for the most carbon-intensive firms.

2.2 EU ETS Allocation and verification process

The EU ETS has been divided into several trading periods. Phase 1 (2005-2007) was a trial period to allow firms and governments to gain experience in emissions trading. Phase 2 (2008-2012) corresponded to the commitment period of the Kyoto Protocol and Phase 3 runs from 2013 till 2020.

In the first and second phase both the total emissions cap and the distribution of allowances were the responsibility of individual Member States. Each state had to design National Allocation Plans (NAPS) for every trading period based on criteria and guidelines set by the European Commission. The NAPS also have to specify how the allowances are distributed among existing installations, new installations and auctions (Neuhoff, 2011). Each Member State has its own registry where changes in the composition of its firms are recorded. The European Central administrator, the Community Independent Transaction Log (CITL), oversees the registry systems and keeps track of emissions and allowances of each EU ETS covered installation (Chevalier, 2012).

Differences between Member States in terms of emissions reduction costs, industrial infrastructure and political views complicated the implementation of the EU ETS. While some states (such as the United Kingdom) wanted strong constraints on emissions, others, including many Eastern European countries, saw constraints as a threat to their potential economic growth (Trotignon and Delbosc, 2008). Betz et al. (2006) analyse how the different approaches selected by Member States increased complexity and reduced transparency of the overall system. Grubb et al. (2005) examine 21 NAPs in Phase 1 and demonstrate that hardly any Member State has allocated less than recent emissions, in many cases contrasting with their obligations under the Kyoto Protocol. The authors argue that the ability for each country to allocate free allowances to its own firms, combined with a flawed basis to the allocation method and corporate lobbying based upon competitive concerns, led to the over-allocation of allowances in Phase 1. Due to the lack of transparency and the severe over-allocation, the price of Phase 1 allowances was highly volatile, eventually converging to zero at the end of the trial period (Walker, 2008). Figure 1 shows the patterns of weekly emission permit futures prices during Phases I and II of the EU ETS. Although the EU ETS includes banking and borrowing within periods, these mechanisms were not allowed across periods so that the two trading sessions are separate. Phase I prices collapsed after April 2006 and then moved to zero by October 2007. Subsequent price fluctuations during Phase II resulted from shifts in demand for energy from weather shocks, deteriorating macroeconomic conditions after 2008, and a continued overallocation of allowances. Phase II prices fell from €30 in 2008 to record lows of €2.81 by January 2013 (Libecap, 2013). Following severe criticism of the way in which allowances were distributed during the first two trading periods, the different national allocation plans have been replaced with a single EU-wide emissions cap in Phase 3.

<<< Insert Figure 1 here >>>

During the first EU ETS phase from 2005 to 2007, almost all emission allowances were allocated for free, a method that is called 'grandfathering'. Most Member States did not take advantage of the EU ETS' provision allowing states to auction 5% of allowances in Phase 1 and 10 % in Phase 2. Only 4 countries used auctioning in Phase 1, accounting for 0.13 % of total allocation.[5] [6]
In Phase 2 more allowances were being auctioned, although the quantity was well below the allowed limit. Contrary to the first 2 phases, auctioning is the default method for allocating allowances in Phase 3. In 2013 more than 40% of allowances will be auctioned, and this share will rise progressively each year (European Commission, 2013).[7]

Every year before 31 March installations covered by the European emissions scheme are required to submit an independently verified report of the amount of carbon emissions for the previous calendar year. Once verified, firms must surrender an equivalent number of carbon allowances to match their actual emissions by the end of April. Firms that do not surrender enough allowances to cover their emissions have to pay a monetary penalty for each excess tonne of CO_2 emitted (€40 per tonne in the first phase and €100 from 2008 on). In addition to penalties, firms have to obtain the missing allowances in the following year and they are “named and shamed” by having their names published.
As already explained in the previous paragraph the EU ETS includes banking and borrowing provisions which is allowed within trading periods. Banking and borrowing between Phase 1 and Phase 2 was not allowed but this prohibition has been removed between Phase 2 and Phase 3.

2.3 EU ETS and firm performance

The literature on various aspects of the EU ETS is growing with much attention being paid to government allocation issues (Ellerman and Buchner, 2008; Neuhoff et al., 2006; Grubb et al., 2005), the influence of the EU ETS on firm performance (Chen et al. 2008; Oberndorfer, 2009) and the drivers of CO_2 prices (Mansanet-Bataller et al. 2007; Alberola et al. 2008; Oberndorfer, 2009).
We will only discuss the studies concerning the impact of the scheme on firm performance. The first set of performance studies considers the effect of the EU ETS on competitiveness and firm profits. Demailly and Quirion (2008) focus on the effect of CO_2 trading on competitiveness for the iron and steel industry, a sector that is strongly exposed to competition from outside the EU. They find that losses in competitiveness due to emission

[5] The auctioning of allowances is governed by the EU ETS Auctioning Regulation. Two auction platforms are in place. The European Energy Exchange (EEX) in Leipzig is the most common platform for the large majority of countries participating in the EU ETS. The second auction platform is ICE Futures Europe (ICE) in London (European Commission, 2013)

[6] Only Denmark, Hungary, Lithuania and Ireland auctioned off 5%, 2.5%, 1.5% and 0.75%, respectively. For a discussion on auctioning versus grandfathering see Goeree et al. (2010).

[7] http://ec.europa.eu/clima/policies/ets/index_en.htm

trading are small for this sector. Convery et al. (2008), based on data in the first EU ETS phase, quantitatively analyze the effect of the carbon price decline on short-term competitiveness of steel, cement, aluminium and refining sectors. The authors confirm the findings of Demailly and Quirion (2008) and discover only a modest influence of carbon price change. The effect of the EU ETS on firm profits has been examined by, among others, Anger (2008). The author concludes that the allowance allocation within the EU ETS framework did not have a significant impact on profits and employment of regulated German firms. Blanco and Rodrigues (2008) bring up a controversial feature of the EU ETS and demonstrate that power producers pass through the costs of freely allocated CO_2 allowances, resulting in so called windfall profits. Sijm et al. (2006) assess the impact of the emissions scheme on electricity prices and provide evidence for windfall profits through rates varying between 60% and 100% of CO2 costs. Chen et al. (2008) and Lise et al. (2010) find similar results, providing strong evidence of electricity price increases caused by the incorporation of the carbon cost. Hoffmann (2007) states that this cost-pass through results in extra costs for energy-intensive companies. In addition to direct costs of buying permits, these firms also have to deal with higher indirect electricity costs.

A second category of performance studies analyzes the relationship between the emission scheme and investment decisions. Rogge et al. (2011) conclude, based on several case studies, that the innovation impact of the trading scheme remains limited because of the scheme's initial lack of stringency and predictability. The authors show that the innovation impact varies greatly across technologies and firms. Not surprisingly, the most carbon-intensive companies and firms with large-scale coal power generation technologies experience the largest impact. Abrell et al. (2011) study the relationship between the amount of allowances and the innovation efforts. Companies which have received excess allocations are shown to undertake fewer investments aiming at reducing pollution, relative to companies which received less allowances compared to their needs. The authors show that the marginal carbon price incentives to reduce emissions have been weakened by the free allocation amounts, reducing the economic efficiency of the scheme.

A third category of research involves the relationship between the EU ETS and stock prices. Oberndorfer (2009) and Veith et al. (2009) find that share prices of ETS-covered electricity producers, were positively correlated with carbon prices. The authors interpret these findings as evidence for the windfall profits mentioned above. Bushnell et al. (2011) confirm these results by using an event study to examine the impact of the carbon price crash in April 2006. They show that the share price of electricity firms declined the most and conclude that the market is strongly focused on the effect of declining carbon prices on revenues through lower electricity prices. The authors also report that the firms with the largest allocated allowances experienced the largest abnormal declines. This result strongly indicates that the market sees emission allowances as a valuable asset.

Other studies using event studies to detect the impact of EU ETS events on stock prices are very scarce. To our best knowledge the only event study relating corporate stock returns to the announcement of verified emissions is Schmidt and Werner (2012). They use a small sample of listed firms from Austria, Denmark, Germany and the UK and find, over the period 2005-2009, a significant negative impact for the publication in 2006 and a positive impact in 2009. The most remarkable results from the cross-correlation analysis are the positive effects from over-allocation on abnormal returns in 2009. The authors conclude that investors see emission allowances as an asset.

3. Hypotheses

In this study we build on previous research on the effects of carbon disclosure on shareholder value. The literature offers various reasons to justify that investors value information about firms' carbon performance.

First, the EU ETS has introduced a price for carbon and made carbon performance a management priority (Egenhoffer, 2007). Companies that are "short" of emission allowances need to buy additional permits to reach compliance with the scheme. On the other hand, companies with excess allowances may sell their excess allowances on the market. According to Johnston et al. (2008) the firm's surplus of allowances is positively related to the firm's market value. The authors argue that unused allowances can be sold or inventoried and used in the future. As a consequence, investors should consider an emission allowance as similar to the firm's other assets and value them as such.

Second, carbon emissions have become an essential element in analyzing a company's risk profile, potential liabilities, and financial performance (Matsumura et al., 2011). Investors recognize that firms with high carbon emission levels and energy-intensive operations are confronted with risks from regulations prompted by concerns about global climate change. Fornaro et al. (2009) state that companies face increasing pressure from their stakeholders to measure, disclose, monitor and manage carbon emissions. Even firms with low emissions will bear the cost of monitoring their carbon performance.

Third, there are threats related to potential changes in the framework of the EU ETS. Investments such as power plants, buildings and infrastructure involve long-term time horizons. Uncertainty about the future carbon price increases costs for both investors in mitigation and investors in polluting technology (Wood and Jotzo, 2011). Stringent emissions caps and a move away from grandfathering to auctioning of allowances from 2013 onwards imply that costs of compliance will go up, thereby increasing the operating costs for the business and lowering the expected profitability.

Fourth, there is a non-compliance risk which can lead to a loss of reputation. Reputation risk includes a decrease in consumer confidence and brand value if the firm is perceived by stakeholders as failing to address climate change risks (Hrasky, 2011).

Based on the argumentation above, we propose the following hypothesis:

H1: The publication of verified carbon emissions contains valuable information to investors.

Several studies provide support for an inverse relationship between carbon emissions and firm value (Konar and Cohen, 2001; Griffin et al., 2012; Lee et al., 2013). Consistent with finance theory that the stock market only reacts to unexpected news, we consider unexpected emissions. Verified emissions below the level of unanticipated emissions are considered as good news and verified emissions larger than expected are perceived as bad news. As already discussed in the previous section, investors should consider an emission allowance as similar to the firm's other assets and value them as such. Unexpected excess allowances comprise a profit factor while unanticipated shortages of allowances represent a cost component. Based on the previous literature and the characteristics of emission allowances, we hypothesize that verified carbon emissions are inversely correlated with market value, as measured by abnormal returns.

H2: The market reaction is negatively associated with unanticipated verified carbon emissions.

In the setting of an emission trading scheme, high carbon-intensive companies face substantial financial risks caused by direct costs and indirect costs such as increased regulatory intervention, abatement expenses, and reputational impact. Chapple et al. (2011) examine the association between high and low carbon-intensity firms and the market value of equity for a sample of Australian firms expected to be affected by a proposed Emission Trading Scheme. The study finds that high carbon-intensive firms suffer from a significantly larger stock decline compared to low carbon-intensity firms. As carbon performance is not a fundamental firm consideration for less carbon-intensity firms, investors may be less concerned with the publication of verified data. We therefore hypothesize that the negative relationship between unexpected verified emissions and market reaction is stronger for carbon-intensive firms.

H3: The negative relationship between unexpected verified emissions and market reaction is stronger for carbon-intensive firms.

4. Data

In this section we present the data used in the empirical application. We begin by describing the event dates of the EU ETS, followed by a description of the firms in our dataset.

4.1 Event dates

In order to investigate how the publication of verified emissions in the European Emissions Trading Scheme (EU ETS) affected stock prices of covered companies, we analyze the 6 dates shown in table 1. On these dates the European Community Transaction Log (henceforth CITL) publicized the verified emissions of the previous year. Except for the years 2006 and 2007, the European Union announced the verified emissions of the previous year on the first day of April. To our best knowledge, the only event study relating stock returns to the announcement of verified emissions is Schmidt and Werner (2012). They use a small sample of listed firms from Austria, Denmark, Germany and the UK and find, over the period 2005-2009, a significant negative impact for the publication in 2006 and a positive impact in 2009.

As already discussed in section 2.2, each Member State is obligated to maintain a registry to track its covered installations. All national registries are connected to the CITL, a central European registry maintained by the European Commission: The CITL gathers in one place all the information from Member States' national registries, which is continually updated due to the constant dialogue between national registries and the CITL. Two kinds of data are publicly available for each installation registered on the CITL database: (1) the number of allowances the installation was allocated through the Member State's National Allocation Plan; and (2) what the installation's emissions were in previous years. This emissions data is collected through a monitoring, reporting and verification process which is operated by private accredited companies and then aggregated at the national level within national registries. (Trotignon and Delbosc, 2008). The verified emissions data are publicized each year on the website of the CITL, accompanied by a press release covered by the European Commission.

<<< Insert Table 1 here >>>

4.2 Sample selection

As we aim at studying the market reaction to 6 EU ETS verification events, our dataset only includes European listed firms with facilities covered by the EU Emissions Trading scheme. We matched the emissions data from the CITL, provided by the Carbon Market Data database[8] to financial data from Thomson Reuters DataStream and firm level accounting data from the Amadeus database produced by Bureau Van Dijk Electronic Publishing.
Unfortunately, the CITL reports allocations and verified emissions at the installation-level rather than at the firm-level and ownership of facilities is reported inconsistently. As a consequence, we need to manually match the installations to firms.
We collect data on EU ETS emissions and allocations at the firm level for publicly-traded firms in two steps. First we identify all EU ETS regulated listed firms. In a next step we select all the facilities owned by the respective firms to aggregate allocated and verified emissions at the company level.

In order to identify all EU ETS regulated listed firms, we select all European publicly traded firms.[9] This information was obtained from the Amadeus database. In a next step we match listed firms with the EU ETS installation database provided by Carbon Market Data. An automatized pre-matching identifies potential matches based on the similarity of company name, installation name and account holder name[10]. In a second step this generous matching is narrowed down by selecting the actual matches from the computer-generated proposed matches. Using this methodology we manage to select 368 listed firms from 25 countries that have installations affected by the EU ETS (see table 2).

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[8]Carbon Market Data is a carbon market research company and data vendor. The Carbon Market Data database is based on information publicized by the CITL (Community Information Transaction Log) and contains all the information on verified and allocated emissions of 12998 installations in the EU ETS.
The Carbon Market Data database provides information about the installation (name, address, contact person) and the account holder of the installation.
[9] Amadeus does not provide time-series data on a firm's listings status and classifies each corporation by its most recent status (either listed or not). We selected a list from Amadeus of firms listed in 2005 and listed in 2010 (most recent available information). Both lists were matched to obtain the full picture of listed firms in the period 2005-2010.
[10] The account holder is the operator who manages the installation's allowances.

To identify all the installations owned by these selected companies, we linked installations' names and account holders' names to companies by company name. Using this procedure we identified 2491 installations. Next we selected a list of subsidiaries of publicly-traded firms with EU ETS obligations. Only majority owned subsidiaries, located in countries covered by the EU ETS and without a link to the parent company by name, were included. After matching the subsidiaries' names with the installation database, another 967 installations could be identified. Finally we checked the e-mail addresses of installation's contact persons and linked an additional number of 75 installations to listed parent companies.

In total, we were able to identify 3533 installations. As there are 12998 installations covered by the EU ETS, our dataset represents 27.2 % of the total number of installations, covering 53 % of total verified emissions in 2011. Table 2 shows the regional distribution of listed firms and installations in our dataset, compared to the distribution of all installations covered by the EU ETS. As can be seen in table 2 we cover the entire European Union, in contrast to similar studies (e.g. Schmidt and Werner, 2012). The countries that are most represented in our sample are the five largest European economies; Germany, the United Kingdom, France, Italy and Spain, account for 53.53% of listed companies and 57.79 % of sample installations. In these five countries there are 48.77 % of the total number of EU ETS facilities located, which shows that our dataset is similarly structured as the population of firms covered by the EU ETS.

<<< Insert Table 2 here >>>

To be included in the analysis, we further impose minimum liquidity requirements to prevent possible biases from thin trading (Campbell et al., 1997). More specific: stocks that had not been traded on at least 50% of all days were excluded. We also analyze press releases by the European Commission to verify if emissions data for all countries were publicized on the event day. For the first event in 2006, the observations (firms as well as installations) were excluded for four Member States; Cyprus, Luxembourg, Malta and Poland. These countries had no operational emission allowances when the first verified emissions were disclosed and had to be excluded from the dataset used to examine the first verification event.

5. Empirical analysis

In this section we first examine the informational content of EU ETS verification events, by studying absolute abnormal returns, followed by a cross sectional analysis of the market reaction itself.

5.1 Informational content of the EU ETS verification events

In an efficient capital market, stock prices on any day fully reflect any changes in the information set of investors (Fama, 1991). The provision of new information about the environmental performance of a firm may cause abnormal changes in its stock price, if this information diverges from the investors' expectations about such performance and is perceived by them to affect the profitability of the firm (Gupta et al., 2005). This is the theoretical framework that underlies the event study methodology to examine the reaction of the capital market to the publication of carbon emissions data. There are various models for carrying out an event study (MacKinlay, 1997). One of them is the market model[11]. Griffin et al. (2012) and Lee et al. (2013) as well as other researchers have used the market model to analyze the market reaction to carbon emissions disclosures. In this study, we use the market model as well.

A large number of previous studies have analyzed the effect of negative environmental news (Capelle-Blancard and Laguna, 2009; Dasgupta et al., 2004; Bettenhausen et al., 2010) and positive environmental news (Curran and Morran, 2007; Gupta and Bishwanath, 2005). Consequently, the null hypothesis of no price reaction can be tested against a signed alternative. The impact of carbon disclosure, within the EU ETS framework, on stock prices depends on the investors' expectations about firms' verified emissions relative to allocated emissions. Depending on these expectations the disclosure of actual emissions can have a positive or negative effect on firm value. Therefore, at this point, no hypothesis is made about the sign of the reaction and we test whether absolute abnormal returns, rather than signed returns are different from the average absolute abnormal return in a pre-event estimation period. This approach is used by different researchers (e.g. Griffin, 2003; De Franco and Hope; 2011; Dettenrieder and Theissen, 2012).

Similar to Lee et al. (2013) we use market-model adjusted absolute abnormal returns. The market model is estimated over 200 trading days ending 20 days prior to the event date. We use MSCI Standard Country indices as our market proxy. Of course, the absolute abnormal return will typically not be zero. We therefore perform our statistical tests on the excess absolute abnormal return, defined as the difference between the actual absolute returns and the average absolute abnormal return during the estimation window. We also consider cumulative excess absolute abnormal returns (CAARs). Note that the CAAR is not equal to the sum of the individual excess absolute abnormal returns. The reason is that we calculate the CAARs by adding the signed abnormal returns and then take the absolute value of the sum. The sum of the individual excess absolute abnormal returns, by contrast, is the sum of absolute returns. It is larger than the CAAR whenever the signs of the abnormal returns are not equal on all days of the event window (Dettenrieder and Theissen, 2012). We use different event windows to capture possible leaks in information and to reflect possible delays in incorporating the information into the stock price. The following event windows are used:
(-1 to +1), (0 to +1), (0 to +2) and (0, +3).[12]

A natural concern with the event study in the context of the same fixed announcement data for all firms is event date clustering. Since the report publications take place at the same time for all firms, cross-sectional correlation might be a problem leading to downward-biased estimates in the standard errors of regression coefficients and thereby overstating the t-statistic (Ingram and Ingram, 1993). To test whether the share prices react significantly to the publication events, controlling for cross-sectional correlation, we use a non-parametric test, as proposed in Corrado (1992). This test does not make any distributional assumptions, focusing

[11] See MacKinlay (1997) on the advantages of the market model.

[12] The estimation window cumulative absolute abnormal return is calculated in a similar way. We add signed abnormal returns in a two-day window, resulting in 100 observations during the 200 estimation window, take the absolute value and then average across the 100 observations. A similar approach is used for the three-day window. The resulting value is than subtracted from the event window cumulative absolute abnormal return to obtain the cumulative excess absolute abnormal return (CAAR).

instead on the rank of the observations instead of their values. Further this test is robust to cross-sectional correlation and event-induced volatility (Corrado, 1992).

<<< Insert Table 3 here >>>

Table 3 shows the absolute abnormal returns. These results indicate that share prices only react to the first publication of verified emissions in 2006, and the first verification event of the second phase in 2009. The excess abnormal return on the event day in 2006 is 0.73% and highly significant. Thus, on average the absolute return on the event date exceeds the average absolute abnormal return during the estimation window by 0.73%. On the compliance event in 2009, the excess abnormal return is 1.09 %.

<<< Insert Table 4 here >>>

The CAARs are reported in table 4. The four event windows surrounding the verification event in 2006 are all highly significant with excess CAARs ranging from 0.90% to 1.63%. The fact that the excess CAARs are not much smaller than the sum of individual excess abnormal returns implies that there is no systematic return reversal during the event window. The excess CAARs around the compliance event in 2009 vary between 0.50% and 2.33 % being significant at the 5 and 10% level.

These results indicate that the financial markets only react to the first publication event of the EU ETS phases and subsequent reports are considered less relevant. On the 15th of May 2006, the day the EU publicized verified emissions data for the first time, investors were informed about the firm's carbon emissions and the net position in allowances for the first time. As already discussed in section 2.1 the allocation levels do not vary within one Phase. The publication of verified emissions in 2007 and 2008 was therefore less relevant as the 2006 report served as a benchmark against which future carbon performance could be forecasted.

The release of 2008 verified emissions data in April 2009 was the first publication in Phase 2 of the EU ETS and, compared to Phase 1, the number of emission allowances was considerably reduced. According to Egenhofer (2009) national allocation plans for Phase 2 have shown major improvements as member states had less leeway on allocation as a result of the need for consistency towards the Kyoto Path. Uncertainty about the firm's position in emission allowances might have led investors to respond to the 2009 publication of verified emissions. Following the same reasoning as above, the publication events in 2010 and 2011 are less interesting to investors as these reports contain less incremental information. These results provide evidence for hypothesis 1, although only the first publication event of each phase seems to contain valuable information to investors.

Another possible explanation to explain the lack of market value relevance of subsequent verification events within each EU ETS phase is the negligible impact of carbon trading on firm performance, due to low carbon prices. As can be seen from Figure 1, the carbon price was at reasonable level during the beginning of each phase but converged to lower levels in subsequent years.

Within the context of an emission trading scheme, high carbon-intensive companies face substantial financial risks caused by increased regulatory intervention, abatement expenses, and reputational impact (Chapple et al., 2011). To assess whether the impact of EU ETS verification events is different for high carbon-intensive firms, we repeat the event study analysis with a subsample of high carbon-intensive firms. We also examine the market reaction with a second subsample consisting of low carbon-intensive firms. We define high (low) carbon-intensive firms as firms with carbon intensity higher (lower) than the sample mean.[13] Carbon intensity is calculated as verified emissions divided by the sales for a given year. Table 5 shows that for the high and low carbon-intensive sample only the first publication events of both phases show significant results. This result confirms the previous findings and shows that the financial markets only react to the first publication event of each EU ETS phase, regardless of the firm's carbon intensity.

<<< Insert Table 5 here >>>

5.2 Determinants of market reactions to EU ETS events

The previous section has shown that the publications of verified emissions in 2006 and 2009 are the only events associated with a statistically significant market reaction. In this section we will examine the determinants that drive the excess abnormal returns on these event days.

First, a naive model is used to define unexpected emissions. The naive model assumes that verified emissions are expected to be equal to allocated emissions from the same year.
In a next step we estimate the expected emissions based on the actual emissions from the previous reporting year adjusted for changes in revenues and changes in allocated emissions. As there is no reliable information about European firms' carbon emissions before the EU ETS took place[14] , we are only able to develop an expectation model for the expected emissions publicized in 2009.
We make the adjustment for sales to account for higher (lower) emissions associated with higher (lower) industrial activity. The release of 2008 verified emissions data in 2009 was the first publication in Phase 2 of the EU ETS and, compared to Phase 1, the number of allocated emissions changed considerably (Egenhofer, 2009). As allocated emissions are known to investors before the verification event and might influence the investors' perception towards verified emissions, we make the adjustment for change in emission allowances. Expected emissions are calculated as follows:

$$Expected\ emissions_t = Emissions_{t-1} * \left(1 + \left(\frac{Revenues_t - Revenues_{t-1}}{Revenues_{t-1}}\right)\right) * \left(1 + \left(\frac{Allocated_t - Allocated_{t-1}}{Allocated_{t-1}}\right)\right)$$

5.2.1 Univariate analysis of the market reaction

To test Hypothesis 2, which predicts that the market reaction is negatively associated with unexpected verified carbon emissions, we compare the cumulative abnormal returns between

[13] We repeated the analysis with the median carbon intensity as threshold. Similar results were obtained and in the interest of space we do not include them.
[14] Prior to the EU ETS, carbon emissions were rarely disclosed and only on a voluntary basis.

firms with more and less emissions than anticipated by the market. We now consider signed abnormal returns as we are interested in the effect of EU ETS determinants on the sign and magnitude of the market reaction. Panel A in table 6 reports the results using the naive model to calculate unexpected emissions. Note that the difference between verified emissions and allocated emissions contains a financial component. Firms with more actual emissions than allocated are short on allowances whereas firms with fewer emissions than allocated have excess allowances. We thus also analyze the difference in market reactions between firms with a long and short position in emission allowances.

As seen in Panel A there are for the 2006 event no significant differences in average CARs between firms with more and less emissions than allocated. The differences in 2009, on the other hand, are highly significant and equal to 1.61 % for event window (0, +1) and 2.59% for event window (0, +2). Firms with a shortage of allowances are punished by investors with negative market reactions equal to -0.71% for event window (0, +1) and -0.21% for event window (0, +2) whereas firms with excess allowances are rewarded with positive market reactions (0.90% and 2.38%).

These results demonstrate that the market reacts positively to firms with fewer emissions than allocated and support hypothesis 2 which states that the market reacts positively to firms with fewer emissions than expected, assuming that expected verified emissions are equal to allocated emissions from the same year.

The difference between the market reaction in 2006 and 2009 seems to indicate that the investors' perception towards emission allowances has changed over time. In 2006, during the trial period of the EU ETS, over-allocation increased price volatility and reduced confidence in the carbon market (Betz and Sato, 2006). High levels of uncertainty about the future of the EU ETS and difficulties to assess the impact of the scheme for a given company, affected the valuation of emission allowances. On 1 April 2009 the verified emissions of 2008, the first year of Phase 2, were disclosed. According to Egenhofer (2009) national allocation plans for Phase 2 have shown major improvements as member states had less leeway on allocation as a result of the need for consistence towards the Kyoto Path. Uncertainty about the firm's position in emission allowances might have led investors to assign a positive price to a firm's excess allowances.

<<< Insert Table 6 here >>>

Panel B in table 6 reports the cumulative abnormal returns between firms with more and less emissions than expected, using the expectation model described in the previous section. The differences in average CARs between firms with more and less emissions than expected are negligible. This result suggests that, contrary to the results using the naive model, investor reactions to the publication of verified emissions do not depend on the number of unexpected emissions relative to expectations. It is important to notice that this result is completely based on the assumption that the model to estimate expected emissions accurately reflects the real expectations of investors about firms' verified emissions.

Hypothesis 3 states that the negative relationship between unexpected verified emissions and market reaction is stronger for carbon-intensive firms. To test this hypothesis, we compare the cumulative abnormal returns following EU ETS verification events between high carbon-intensive firms and low carbon-intensive firms with two subsamples: one subsample comprising the firms with a surplus of allowances and one subsample comprising the firms with a shortage of allowances. We define high carbon-intensive firms as firms with carbon intensity higher than the sample median.[15] Carbon intensity is calculated as verified emissions divided by the sales for a given year. The results reported in table 7, show that carbon-intensive firms have, during the 2006 event, higher cumulative abnormal returns in the underallocation subsample and lower cumulative abnormal returns in the overallocation subsample, although both insignificant. The 2009 event shows the opposite results with a significant difference for the three days event window indicating that carbon-intensive firms are penalized stronger for having a shortage of carbon allowances. These different results between the 2006 and 2009 event are in line with previous findings suggesting that the investors' perception towards emission allowances has changed over time

<<< Insert Table 7 here >>>

5.2.2 Multivariate analysis of the market reaction

In this section we report some OLS regression analyses in order to further explore the drivers for the market reaction following the 2006 and 2009 verification event.

We consider the following equation:

$$(1)\ \ \text{CAR}_i = \alpha + \beta_1 \text{ Carbon determinant }_i + \beta_2 \text{ Size }_i + \beta_3 \text{ Market to book }_i + \beta_{4-10} \text{ Industry Dummy}_i + \varepsilon_i$$

The dependent variable is the cumulated abnormal return over event windows (0, +1) and (0, +2). Carbon determinant refers to four alternative variables to proxy for unexpected emissions: Underallocation (UA) is calculated as the difference between verified emissions and allocated emissions divided by allocated emissions and is a measure for unexpected emissions following the naive model. The dummy Net Position (NP) refers to a variable which is 1 if firm i has a shortage of allowances and 0 if firm i has excess allowances. Unexpected Emissions (UE) is calculated as the difference between verified emissions and expected emissions, as calculated by the expectation model described in section 5.1, divided by expected emissions. The dummy Unexpected Position (UP) refers to a variable which is 1 if firm i experienced more emissions than expected, as calculated by the expectation model, and 0 otherwise.

Firm size has been found to be influential in several environmental event studies (e.g. Klassen and McLaughlin, Hendricks and Singhal, 2003). Typically, smaller firms have stronger market reactions than larger firms due to the greater relative impact of any one event to the firm's profits. Also, since smaller firms tend to be less closely followed by analysts, disclosures of verified emissions may have more of a surprise element as compared to announcements by larger firms (Jacobs et al., 2010). Therefore Size measured by the natural

[15] We repeated the analysis with the mean carbon intensity as threshold. Similar results were obtained and in the interest of space we do not include them.

logarithm of market capitalization is added to the model as a control variable. The variable Market to book is used as a proxy for growth opportunities. To control for the possible impact of industrial affiliation, we include industry dummy variables.
The description of all the variables used in this study, is presented in table 8 and summarised in table 9. The firms vary widely in size as can be seen from the large standard deviations of market capitalization. The average firm over the period 2006-2011 is long in emission allowances, ranging from 11% in 2006 to 20.9% in 2010. The average emission intensity reaches with 0.527% a maximum in 2007 and with 0.297% a minimum in 2011.

<<< Insert Table 8 here >>>

<<< Insert Table 9 here >>

Table 10 presents industrial and EU ETS emission characteristics. As can be seen from this table below, the most represented industry in our sample is Consumer Goods accounting for 23.91% of all firms. However, this industry does not play an important role in the EU ETS, receiving less than 2% of total carbon allowances. Utilities, on the other hand, clearly dominates the other industries in terms of allocated certificates; 56.24% of all free carbon certificates in Phase I and 47.90% in Phase 2 are allocated to utility firms while they are responsible for nearly 60% of verified emissions. The second largest emitter, relative to the number of firms is the Oil and Gas industry. The industries Basic Resources and Construction complete the list of large emitters. The differences between allocated and verified emissions reveal that only the utilities are short on allowances, which confirms the findings of Ellerman and Buchner (2008) and Betz et al. (2006).

<<< Insert Table 10 here >>

Table 11 reports the coefficient estimates for the 2006 verification event. As we are not able to develop an expectation model for the expected emissions publicized in 2006, we only report the models with the underallocation determinants. As can be seen, Underallocation and Net Position have the expected signs, however only Underallocation has a significant negative impact on abnormal returns over the event window (0, +2). This result indicates that verified emissions relative to allocated emissions are negatively correlated to abnormal returns.
There is no evidence found to support the findings of, amongst others, Hendrick and Signal (2003) that smaller firms have stronger market reactions than larger firms. On the contrary, we find a significant positive effect of Size on abnormal returns over the event window (0, +2).

<<< Insert Table 11 here >>>

Table 12 reports the coefficient estimates for the 2009 verification event. The results demonstrate expected negative signs for the determinants Underallocation and Net Position. The Net Position coefficient is equal to -0.020 over event window (0, +1) and -0,028 over event window (0, +2). The coefficients of Unexpected Emissions and Unexpected Position have, contrary to expectation, positive signs. Both EU ETS determinants are however insignificantly different from zero, indicating that unexpected changes in verified emissions have no impact on firm value.

<<< Insert Table 12 here >>>

These findings provide evidence for hypothesis 2 which states that the market reacts positively to firms with fewer emissions than expected, assuming that expected verified emissions are equal to allocated emissions from the same year. The variables related to unexpected emissions, calculated by the expectation model have no explaining power. These results suggest that the naive model outperforms the expectation model in accurately reflecting the market's expectations about carbon emissions.

To test hypothesis 3, which states that the negative relationship between unexpected verified emissions and market reaction is stronger for carbon-intensive firms, interaction terms were constructed by multiplying the carbon intensity variable and the Underallocation determinant.[16] The Underallocation determinant is used as the naive model is found to outperform the expectation model. We use three alternative variables to proxy for carbon intensity: (1) Emission Intensity (Intensity) is calculated as the ratio of verified carbon to sales for a given year; (2) the dummy Carbon intensive median (Median) equals one if the company's emission intensity is higher than the sample median emission intensity and equals null otherwise and (3) the dummy Carbon intensive mean (Mean) equals one if the company's emission intensity is higher than the sample average emission intensity and equals null otherwise A detailed description of the variables can be found in table 8. Table 13 and table 14 report the results for verification event 2006 and 2009.

<<< Insert Table 13 here >>>

<<< Insert Table 14 here >>>

The results for the 2006 event provide no evidence for a stronger negative relationship between unexpected verified emissions and abnormal returns for carbon-intensive firms. The coefficients of the three interaction terms for the 2009 event, however, enter the regressions with the expected signs. These results, robust to alternative carbon intensity definitions, reveal that high-carbon intensive companies are penalized (rewarded) more for having a shortage (surplus) of allowances.

The different results between 2006 and 2009 are in line with the results reported in table 11 and 12 and suggest that the investors' perception towards emission permits has changed over time. Hoffman et al. (2008) argue that there were high levels of uncertainty about the future of the emission scheme during the first period. These high levels of uncertainty regarding the future of the EU ETS and difficulties to assess the impact of the scheme for a given company, affected the valuation of emission allowances during the first phase. Uncertainty about the future of the scheme decreased as the long-term reduction target for 2020 was set in 2008

[16] We also constructed interaction terms by multiplying the carbon intensity variable and the Net Position dummy. Similar results were obtained and in the interest of space we do not include them.

(Abrell et al, 2011). This change in perception towards the future of the scheme and valuation of emission allowances might explain the differences in market reaction between the 2006 and 2009 event.

6. Conclusion

In this study we examine the impact of 6 publications of verified emissions, within the context of the European Union Emission Trading Scheme, on market value.

To analyze the informational impact of these verification events, we use absolute abnormal returns, instead of signed abnormal returns. We follow this approach as it is not clear whether the publication of verified emissions conveys good or bad news to investors. We thus analyze whether publication of carbon data changes stock prices but are uncertain about the direction of the price change.

The results of the event study demonstrate that 2 verification events over the period 2006-2011 result in statistically significant market responses. The two significant events are the first publication of verified emissions in the first EU ETS phase, a pilot period that ran from 2005 to 2007, and the first publication in the second phase, coinciding with the Kyoto Protocol commitment period of 2008 - 2012. These findings show that investors value particularly the information revealed at the first publication event of each EU ETS phase. As the allocation levels do not change within one phase, subsequent verification events in each phase are less informative as the first year's report served as a benchmark on the basis of which future carbon emissions could be estimated.

We further document a significant negative correlation between the market reaction and the level of unexpected emissions, especially during the first publication in the second phase, which is consistent with the view that verified emissions below the level of unanticipated emissions are considered as good news and verified emissions larger than expected are perceived as bad news.

No evidence is found for a negative association between unexpected verified carbon emissions, as calculated by an expectation model, and abnormal returns. This result suggests that the naive model, which assumes that verified emissions are expected to be equal to allocated emissions from the same year, outperforms the expectation model in accurately reflecting the investors' expectations about carbon emissions.

Finally, we find strong evidence that the negative relationship between unexpected verified emissions and market reaction is significantly stronger for carbon-intensive firms, although only during the first publication event of the second phase.

The different results between 2006 and 2009 suggest that the investors' perception towards emission permits has changed over time.

It is important to recognize some caveats that must be applied to interpret these results. First, the cross-sectional results in this study are partially based on the assumption that the model to estimate expected emissions accurately reflects the real expectations of investors about firms' verified emissions. Further research is needed to determine and improve the accuracy of this model.

Second, short-term reactions of investors to the verification events, could differ considerably from the long-term valuation of carbon performance. In this regard, future research should investigate the impact of carbon performance, within the framework of the EU ETS, on long-term financial performance indicators such as Tobin's Q.

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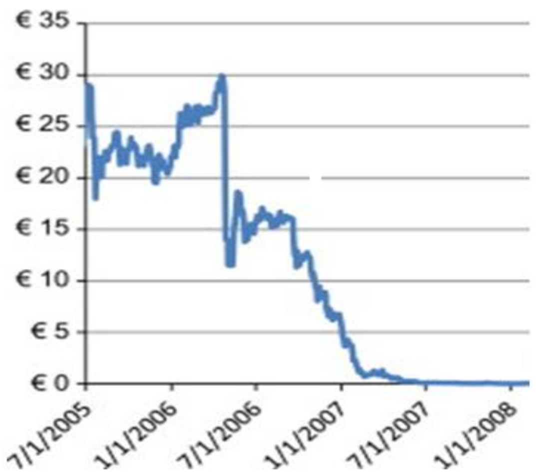
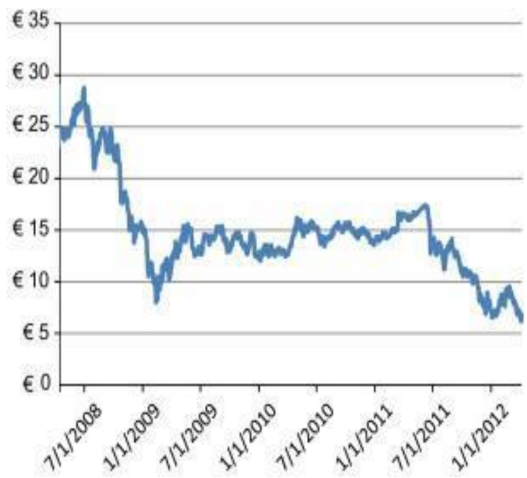
Figure 1: Evolution of the carbon price

Phase 1



Phase 2



Source: Venmans (2012)

Table 1: Event dates

Event	Description
15/05/2006	Publication 2005 verified emissions (1st phase)
2/04/2007	Publication 2006 verified emissions (1st phase)
1/04/2008	Publication 2007 verified emissions (1st phase)
1/04/2009	Publication 2008 verified emissions (2nd phase)
1/04/2010	Publication 2009 verified emissions (2nd phase)
1/04/2011	Publication 2010 verified emissions (2nd phase)

Source: CITL

Table 2: Regional distribution of listed firms, sample installations and CITL installations

This table reports the distribution of listed firms with installations covered by the EU ETS across countries.

Country	Listed Firms	%	Installations Sample	%	Installations EU ETS	%
Austria	8	2.17%	72	2.04%	228	1.75%
Belgium	12	3.26%	163	4.61%	367	2.82%
Bulgaria	8	2.17%	29	0.82%	151	1.16%
Cyprus	0	0.00%	0	0.00%	13	0.10%
Czech Republic	7	1.90%	139	3.93%	427	3.29%
Denmark	9	2.45%	54	1.53%	409	3.15%
Estonia	0	0.00%	19	0.54%	58	0.45%
Finland	13	3.53%	126	3.57%	662	5.09%
France	41	11.14%	382	10.81%	1130	8.69%
Germany	54	14.67%	604	17.10%	2012	15.48%
Greece	7	1.90%	55	1.56%	164	1.26%
Hungary	5	1.36%	67	1.90%	274	2.11%
Iceland	0	0.00%	1	0.03%	4	0.03%
Ireland	5	1.36%	26	0.74%	125	0.96%
Italia	28	7.61%	352	9.96%	1215	9.35%
Latvia	4	1.09%	9	0.25%	111	0.85%
Liechtenstein	0	0.00%	0	0.00%	2	0.02%
Lithuania	10	2.72%	26	0.74%	114	0.88%
Luxembourg	1	0.27%	6	0.17%	15	0.12%
Malta	0	0.00%	0	0.00%	2	0.02%
Netherlands	12	3.26%	134	3.79%	448	3.45%
Norway	5	1.36%	55	1.56%	121	0.93%
Poland	17	4.62%	184	5.21%	943	7.25%
Portugal	8	2.17%	48	1.36%	284	2.18%
Romania	10	2.72%	56	1.59%	280	2.15%
Slovakia	8	2.17%	10	0.28%	203	1.56%
Slovenia	6	1.63%	49	1.39%	100	0.77%
Spain	23	6.25%	316	8.94%	1154	8.88%
Sweden	16	4.35%	107	3.03%	834	6.42%
UK	51	13.86%	444	12.57%	1148	8.83%
TOTAL	368	100%	3533	100%	12998	100%

Source: own calculations based on data provided by Carbon Market Data

Table 3: Investor reactions to EU ETS verification events – Excess Absolute Abnormal Returns

This table shows the event study results for individual days during the event window. The first line reports the mean excess absolute abnormal return, defined as the absolute abnormal return minus the average abnormal return observed during the estimation period. The second line reports a Corrado Rank test statistic (Corrado, 1992). *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

	AAR(-1)	AAR(0)	AAR(1)	AAR(2)
2006	0.30 (1.36)	0.73 (1.76)	0.27 (1.27)	0.23 (1.35)
	1.55	*3.33****	*1,74**	*1,59*
2007	-0.16 (0.87)	0.01 (1.05)	-0.02 (1.01)	-0.07 (0.97)
	-0.7	*0.18*	*0.01*	*-0.19*
2008	0.05 (1.49)	0.57 (2.00)	0.10 (1.53)	0.03 (1.46)
	0.28	*1.55*	*0.39*	*0.22*
2009	0.38 (2.32)	0.38 (2.32)	1.09 (3.03)	0.95 (2.88)
	0.57	*0.57*	*1.75**	*1.82**
2010	-0.24 (1.09)	-0.01 (1.33)	0.04 (1.37)	-0.14 (1.18)
	-1.08	*0.335*	*-0.47*	*-0.14*
2011	-0.15 (1.05)	0.02 (1.14)	0.17 (1.29)	-0.01 (1.11)
	-0.69	*0.10*	*0.65*	*-0.26*

Table 4: Investor reactions to EU ETS verification events – Excess Cumulative Absolute Abnormal Returns

This table shows the event study results for different windows surrounding the EU ETS verification events. The first line reports the mean cumulative excess absolute abnormal return, defined as the cumulative absolute abnormal return minus the average cumulative abnormal return observed during the estimation period. The second line reports a Corrado Rank test statistic (Corrado, 1992). *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

	CAAR[-1.1]	CAAR[0.1]	CAAR[0.2]	CAAR[0.3]
2006	1.13 (2.95)	0.90 (2.37)	0.99 (2.81)	1.63 (3.69)
	*3.77****	*3.52****	*3.79****	*3.79****
2007	-0.17 (1.63)	-0.04 (1.43)	-0.00 (1.79)	-0.00 (1.79)
	-0.34	*0.14*	*-0.06*	*-0.06*
2008	0.28 (2.84)	0.35 (2.42)	0.11 (2.69)	0.11 (2.69)
	0.55	*1.13*	*0.40*	*0.40*
2009	1.28 (4.73)	1.16 (3.93)	2.11 (5.55)	2.33 (4.03)
	1.43	*1.76**	*2.15***	*2.04***
2010	0.12 (2.45)	0.21 (2.11)	0.23 (2.56)	0.23 (2.56)
	0.06	*-0.04*	*0.21*	*0.21*
2011	-0.02 (1.98)	0.14 (1.75)	0.17 (2.18)	0.17 (2.18)
	-1.18	*-0.30*	*-0.46*	*-0.46*

Table 5: Investor reactions to EU ETS verification events – Excess Cumulative Absolute Abnormal Returns for high carbon-intensive firms and low carbon-intensive firms.

This table shows the event study results for high carbon-intensive firms (A) and low carbon-intensive firms (B). High (low) carbon-intensive firms are defined as firms with carbon intensity higher (lower) than the sample mean. The first line reports the mean cumulative excess absolute abnormal return, defined as the cumulative absolute abnormal return minus the average cumulative abnormal return observed during the estimation period. The second line reports a Corrado Rank test statistic (Corrado, 1992).
*, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

	A CAAR [0,1]	B CAAR [0,1]
2006	0.95 (2.42)	0.82 (2.29)
	*3.58****	*2.89****
2007	0.08 (1.54)	-0.05 (1.41)
	1.30	*0.11*
2008	0.24 (2.31)	0.38 (2.45)
	1.24	*1.10*
2009	1.73 (4.56)	1.00 (3.77)
	*1.86**	*1.71**
2010	0.05 (2.03)	-0.03 (1.81)
	-0.30	*0.15*
2011	-0.18 (1.49)	0.25 (1.84)
	-0.33	*-0.24*

Table 6: Comparison between higher and lower emissions than expected

This table shows the difference in average CARs between firms with more and less emissions than expected, across publication events for the (0, +1) and (0, +2) event windows. Panel A reports the differences according to the naive model. Panel B reports the differences according to the expectation model. T-tests for equality of means are carried out with p-values reported between brackets.
***, **,* denote significance at the 10%, 5% and 1% level.
Panel A: 241 observations in 2006 (69 firms emitting more, 172 emitting less than expected)
269 observations in 2009 (69 firms emitting more, 200 emitting less than expected)
Panel B: 253 observations in 2009 (91 firms emitting more, 162 firms emitting less than expected).

		15/05/2006 (0, +1)	15/05/2006 (0, +2)	01/04/2009 (0, +1)	01/04/2009 (0, +2)
(A)	Emitting less	-0.0122	-0.0159	0.0090	0.0238
	Emitting more	-0.0127	-0.0166	-0.0071	-0.0021
	Difference	0.0005 (0.890)	0.0007 (0.868)	0.0161 (0.001)***	0.0259 (0.000)***
(B)	Emitting less			0.0087	0.0239
	Emitting more			0.0083	0.0235
	Difference			0.0004 (0.944)	0.0004 (0.961)

Table 7: Comparison of CAARs between high carbon-intensive companies and low-carbon intensive companies

This table shows the difference in average CARs between high-carbon intensive firms and low-carbon intensive firms for the (0, +1) and (0, +2) event windows. Panel A reports the differences for firms with a surplus of allowances. Panel B reports the differences for firms with a shortage of allowances. T-tests for equality of means are carried out with p-values reported between brackets.
***, **,* denote significance at the 10%, 5% and 1% level.
Panel A: 172 observations in 2006 (85 low-carbon, 87 high-carbon)
200 observations in 2009 (97 low-carbon, 103 high-carbon)
Panel B: 69 observations in 2006 (35 low-carbon, 34 high-carbon).
69 observations in 2009 (36 low-carbon, 33 high-carbon)

		15/05/2006 (0, +1)	15/05/2006 (0, +2)	01/04/2009 (0, +1)	01/04/2009 (0, +2)
(A)	High	-0.0143	-0.0200	0.0183	0.0359
	Low	-0.0110	-0.0133	0.0107	0.0284
	Difference	0.0033 (0.405)	0.0067 (0.166)	0.0076 (0.245)	0.0075 (0.419)
(B)	High	-0.0120	-0.0120	-0.0119	-0.0158
	Low	-0.0176	-0.0195	-0.0017	0.0134
	Difference	0.0056 (0.418)	0.0075 (0.294)	0.0102 (0.268)	0.0292 (0.037)**

Table 8: Description of the variables

Variable	Description
Size	Size is measured as the logarithm of the firm's Market capitalization. It is measured in thousands. Source: DataStream
Revenues	Revenues represent gross sales and other operating revenues less discounts, returns and allowances. Source: Worldscope
Verified emissions	Actual carbon emissions over the year are measured in millions.
Allocated emissions	Allocated carbon emissions over the year are measured in millions.
Market to book (MTB)	This is defined as the market value of the ordinary (common) equity divided by the balance sheet value in the company. Source: Worldscope
Industry	The firm's industrial affiliation is assessed on the Industry Classification Benchmark. Source: DataStream
Underallocation (UA)	The difference between verified emissions and allocated emissions divided by allocated emissions
Net Position (NP)	Dummy NP, equals 1 if firm i has a shortage of allowances and 0 otherwise
Unexpected emissions (UE)	The difference between verified emissions and expected emissions, calculated by the expectation model, divided by expected emissions
Unexpected Position (UP)	Dummy UP, equals 1 if firm i experienced more emissions than expected and 0 otherwise
Emission Intensity (Intensity)	Verified carbon emissions divided by the sales for a given year
Carbon intensive mean (Mean)	Dummy Mean, equals 1 if firm i 's emission intensity is higher than the sample average emission intensity and 0 otherwise
Carbon intensive median (Median)	Dummy Median, equals 1 if firm i 's emission intensity is higher than the sample median emission intensity and 0 otherwise

Table 9: Firm characteristics

This table presents the descriptive statistics of the listed firms in our sample over the period 2006 to 2011. We report means of each variable with standard deviations between brackets.

	2006	2007	2008	2009	2010	2011
Market Capitalization (in million €)	25331 (132976)	28298 (173156)	30597 (157522)	17279 (72141)	18077 (63854)	21023 (67837)
Revenues (in million €)	26170 (152157)	28161 (173156)	27275 (154620)	33172 (210628)	18585 (46370)	21574 (55068)
Verified emissions (in 000)	3495 (13418)	3325 (158729)	3393 (13162)	3541 (13097)	3093 (11317)	2938 (11232)
Allocated emissions (in 000)	3475 (13419)	3196 (12191)	3338 (12639)	3166 (10128)	3211 (10103)	3117 (10099)
Overallocation	0.110 (0.263)	0.129 (0.28023)	0.163 (0.835)	0.124 (0.272)	0.209 (0.276)	0.174 (0.281)
MTB	2.013 (1.598)	1.923 (1.255)	2.05 (1.373)	2.536 (1.494)	1.805 (1.612)	2.610 (1.324)
Emission Intensity	0.384 (0.763)	0.527 (1.231)	0.329 (0.647)	0.363 (0.753)	0.337 (0.610)	0.297 (0.508)

Table 10: Distribution of sample companies across industries

This table reports the distribution of listed companies with installations covered by the EU ETS across industries. Allocated allowances for each industry are reported as a percentage of all allowances received by the firms in the dataset. Verified emissions for each industry are estimated and presented in a similar fashion.

Industry	Number of firms	Number of firms (% of sample)	Allocated allowances (% of sample)		Verified emissions (% of sample)	
Consumer Goods	88	23.91%	Phase1:	1.78%	Phase1:	1.45%
			Phase2:	1.91%	Phase2:	1.54%
Industrial	65	17.66%	Phase1:	2.42%	Phase1:	2.11%
			Phase2:	2.99%	Phase2:	2.19%
Basic Resources	45	12.23%	Phase1:	12.39%	Phase1:	10.12%
			Phase2:	13.95%	Phase2:	9.49%
Utilities	41	11.14%	Phase1:	56.24%	Phase1:	59.92%
			Phase2:	47.90%	Phase2:	58.31%
Construction	40	10.87%	Phase1:	11.70%	Phase1:	11.25%
			Phase2:	14.48%	Phase2:	10.69%
Chemicals	38	10.33%	Phase1:	3.48%	Phase1:	3.30%
			Phase2:	5.11%	Phase2:	4.11%
Oil & Gas	31	8.42%	Phase1:	11.61%	Phase1:	11.53%
			Phase2:	13.27%	Phase2:	13.35%
Healthcare	20	5.43%	Phase1:	0.39%	Phase1:	0.32%
			Phase2:	0.39%	Phase2:	0.33%

Table 11: Cross-correlation results -Verification event 2006-

This table shows OLS estimation results for the following equation: CAR = α + β_1Carbon determinant + β_2 Size + β_3 Market to book + β_{4-10} Industry Dummy + ε. The Carbon determinants are Underallocation (UA) and the dummy Net Position (NP). We report OLS coefficients, the adjusted R^2 and the p-value (F-statistic). We report significance levels for 1% (***), 5 %(**) and 10 % (*).

	Panel A: Event window (0, +1)		*Panel B: Event window (0, +2)*	
	(1)	(2)	(1)	(2)
Intercept	-0.036***	-0.033**	-0.058***	-0.054***
	(0.006)	(0.011)	(0.000)	(0.001)
UA	-0.008	-	-0.013*	-
	(0.234)		(0.089)	
NP	-	-0.002	-	-0.001
		(0.672)		(0.888)
Size	0.001	0.001	0.002*	0.002
	(0.274)	(0.435)	(0.077)	(0.102)
MTB	0.001	0.001	0.001	0.001
	(0.513)	(0.604)	(0.443)	(0.442)
Industry-FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.109	0.071	0.083	0.049
P-value	0.000	0.001	0.001	0.012
Obs.	241	241	241	241

Table 12: Cross-correlation results -Verification event 2009-

This table shows OLS estimation results for the following equation: CAR = α + β_1Carbon determinant + β_2 Size + β_3 Market to book + β_{4-10} Industry Dummy + ε. The Carbon determinants are Underallocation (UA), Unexpected Emissions (UE) and the dummies Net Position (NP) and Unexpected Position (UP). We report OLS coefficients, the adjusted R^2 and the p-value (F-statistic). We report significance levels for 1% (***), 5 %(**) and 10 % (*).

Panel A: Event window (0, +1)

	(1)	(2)	(3)	(4)
Intercept	0.006 (0.815)	-0.014 (0.593)	0.058 (0.007)	0.041* (0.065)
UA	-0.027** (0.017)			
NP		-0.020*** (0.002))		
UE			0.005 (0.576)	
UP				0.003 (0.620)
Size	-0.000 (0.966)	0.004 (0.789)	-0.003* (0.081)	-0.002* (0.092)
MTB	-0.003* (0.077)	-0.003* (0.096)	-0.002 (0.348)	-0.002 (0.276)
Industry-FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.057	0.073	0.044	0.043
P-value	0.004	0.001	0.022	0.022
Obs.	265	265	251	251

Panel B: Event window (0, +2)

	(1)	(2)	(3)	(4)
Intercept	-0.0147 (0.644)	-0,041 (0,248)	0.058* (0.085)	0.006 (0.874)
UA	-0.037** (0.020)			
NP		-0.028*** (0.002)		
UE			0.016 (0.262)	
UP				0.006 (0.505)
Size	0.001 (0.504)	0.0019 (0.337)	0.000 (0.919)	0.001 (0.725)
MTB	-0.006** (0.018)	-0.005** (0.026)	-0.005** (0.023)	-0.005 (0.100)
Industry-FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.127	0.141	0.106	0.110
P-value	0.000	0.000	0.000	0.000
Obs.	265	265	251	251

Table 13: Cross-correlation results –High versus low carbon-intensity firms- Verification event 2006

This table shows OLS estimation results for the following equation: CAR = α + β_1UA + β_2 Carbon Intensity determinant + β_3 Carbon Intensity determinant * UA + β_4 Size + β_5Market to book + β_{6-12} Industry Dummy + ε. The Carbon Intensity determinants are the dummy Carbon Intensity median (Median), the dummy Carbon Intensity mean (Mean) and the continuous variable Carbon Intensity (Intensity).
We report OLS coefficients, the adjusted R² and the p-value (F-statistic). We report significance levels for 1% (***), 5 %(**) and 10 % (*).

	Panel A: Event window (0, +1)			*Panel B: Event window (0, +2)*		
	(1)	(2)	(3)	(1)	(2)	(3)
Intercept	-0,026* (0,069)	-0,025* (0,051)	-0,024* (0,065)	-0,048*** (0,006)	-0,069*** (0,000)	-0,047*** (0,004)
UA	-0,010 (0,279)	-0,003 (0,676)	-0,005 (0,729)	-0,021* (0,059)	-0,014 (0,162)	-0,010 (0,573)
Median	-0,001 (0,900)			0,000 (0,948)		
Median*UA	0,016 (0,573)			0,018 (0,376)		
Mean		-0,004 (0,365)			0,000 (0,986)	
Mean*UA		-0,007 (0,278)			-0,001 (0,584)	
Intensity			-0,001 (0,431)			0,000 (0,899)
Intensity*UA			0,000 (0,887)			0,001 (0,708)
Size	0,001 (0,160)	0,001* (0,094)	0,001 (0,239)	0,003** (0,022)	0,001** (0,026)	0,002** (0,034)
MTB	0,000 (0,716)	0,001 (0,824)	0,000 (0,746)	0,001 (0,609)	0,001 (0,593)	0,001 (0,606)
Industry-FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R²	0,108	0,112	0,110	0,146	0,091	0,091
P-value	0,000	0,000	0,000	0,001	0,001	0,001
Obs.	241	241	241	241	241	241

Table 14: Cross-correlation results –High versus low carbon-intensity firms- Verification event 2009

This table shows OLS estimation results for the following equation: CAR = α + β_1UA + β_2 Carbon Intensity determinant + β_3 Carbon Intensity determinant * UA + β_4 Size + β_5Market to book + β_{6-12} Industry Dummy + ε. The Carbon Intensity determinants are the dummy Carbon Intensity median (Median), the dummy Carbon Intensity mean (Mean) and the continuous variable Carbon Intensity (Intensity).
We report OLS coefficients, the adjusted R² and the p-value (F-statistic). We report significance levels for 1% (***), 5 %(**) and 10 % (*).

	Panel A: Event window (0, +1)			*Panel B: Event window (0, +2)*		
	(1)	(2)	(3)	(1)	(2)	(3)
Intercept	0,012 (0,639)	0,017 (0,517)	0,012 (0,621)	0,036 (0,291)	-0,041** (0,042)	-0,034 (0,322)
UA	-0,011 (0,460)	-0,012 (0,405)	-0,053** (0,012)	-0,002 (0,930)	-0,006 (0,761)	-0,082** (0,017)
Median	0,002 (0,726)			0,007 (0,463)		
Median*UA	-0,040* (0,070)			-0,077** (0,016)		
Mean		0,007 (0,335)			0,004 (0,710)	
Mean*UA		-0,048* (0,083)			-0,062* (0,097)	
Intensity			-0,003 (0,124)			-0,002 (0,276)
Intensity*UA			-0,007* (0,097)			-0,012** (0,040)
Size	0,001 (0,921)	0,001 (0,743)	0,000 (0,916)	0,002 (0,427)	0,001 (0,492)	0,002 (0,308)
MTB	-0,003 (0,110)	-0,003* (0,091)	-0,007* (0,010)	-0,004* (0,088)	-0,005** (0,042)	-0,001* (0,066)
Industry-FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R²	0,096	0,085	0,093	0,146	0,122	0,123
P-value	0,001	0,000	0,000	0,001	0,000	0,000
Obs.	265	265	265	265	265	265